SWAY OF SKYSCRAPERS

By FRANK DICKERSON, JR., '27

EDITOR'S NOTE.—Mr. Dickerson is the holder of the American Institute of Steel Construction Fellowship for this year. Under the direction of Professor C. T. Morris, of the civil engineering department, Mr Dickerson is making a study of wind stresses in tall building frames, and is using the A. I. U. tower in Columbus as the subject of his investigations.
The American Institute of Steel Construction Fellowship of last year was held by Howser C. Hunt.

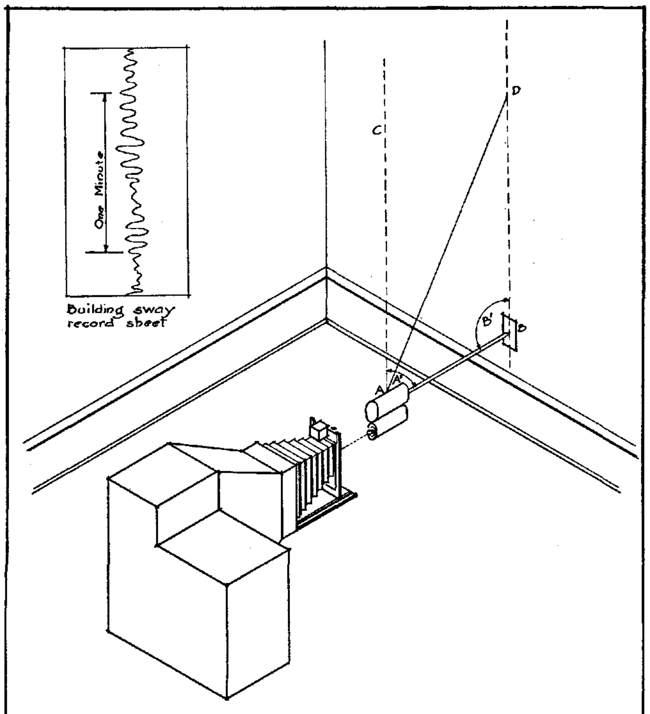
Did you ever stand on the top of a twelve-foot wobbly pitching stepladder and, in your attempt to keep an even keel, describe such a series of curves that it would require a six-foot equation to plot them? This will give you an exaggerated idea of the problems that arise in tall buildings.

Not so many years ago, people were awed by the erection of a ten-story building; even the owners, the architects, the engineers, and the builders were a little dubious as to the outcome. To play safe, these buildings were built massive; they proved very safe and solid. As more were built, and as they grew story by story, the massiveness of the construction was pared down, and the economical steel spider-web construction of today developed. This new type of construction is perfectly safe; but in the search for a perfect construction, another factor has entered—sway. Sway has halted the search for the most economical construction, and may put us back into the designs of a few years ago.

If sway were necessary, for safety or for some architectural or engineering reason, it would become just another consideration in the process of design. It is not dangerous to have this motion, but it is uncomfortable to the occupants of the building. It is more of a psychological than an engineering problem.

People in the old ten-story building were not bothered by building movements because there were none. Today, in the tall modern structure, there is movement; one quarter of an inch is not uncommon during storms, and even this slight eccentricity is enough to upset the organs of equilibrium of a few people. Some of the most recent buildings have a movement of about three-fourths of an inch, which approaches very close to the "threshold of sensation of the average man or woman." For every person who can feel one-quarter of an inch movement, there are probably ten who can detect a three-quarters of an inch motion.

You will probably never find a hanging fixture in the upper stories of a tall building, because it will have perceptible motion, and if it should be of a certain length the motion would be magnified. Even if the persons in the room could not detect the motion, the exaggerated oscillations of the fixture would play heavily upon their nerves and imaginations. It is amusing to hear the stories that are told about the wild maneuvering of buildings during storms. Even on a quiet day, people going to the top of the A. I. U. tower, in Columbus, believe that they feel the building sway under them. Whether people actually detect this motion or whether they imagine they do, it causes the renting agents no end of trouble in maintaining a normal occupancy of their buildings.



SWAY PHOTOR

At the Ohio State University there is an American Institute of Steel Construction Fellowship under the direction of Professor C. T. Morris, of the civil engineering department, which was created for the purpose of studying wind stresses in tall building frames. In 1925-26 A. Ward Ross, holder of the Robinson Fellowship, with Professor Morris developed the Ross Method for calculating wind stresses in tall buildings. The A. I. U. Building was used as the basis and the example for this research, and is reviewed in The Ohio State University Engineering Experiment Station Bulletin 48.

In 1928-29 Howser C. Hunt was awarded the American Institute of Steel Construction Fellowship in order to continue the study of the effect that wind has on tall buildings. A wind direction apparatus and an anemometer were installed upon the top of the A. I. U. tower. These gave the direction of the wind and the velocity of the wind respectively. An apparatus was designed and built to register the wind pressure against the sides of the building. Twelve of these pressure-recording boxes, as they are called, were made so as to record the pressure at three points on all four sides simultaneously.

The wind stresses in buildings are due to the sway or the bending produced by strong winds acting against the surfaces of the structure. During the strong spring winds last year, different tests were made trying to determine the amplitude of vibration of the A. I. U. tower but no sway was detected. This did not prove that there was no motion, but it did show that the movement was very slight, even in a high wind. Three different ways were tried to detect this movement. In one, a theodolite was placed in the bottom of an elevator shaft and sighted on cross-section paper at the thirty-second floor level. In the second, a transit was set up on the ground about two blocks south of the tower. The line of sight was at right angles to direction of the wind, so the greatest movement of the building was also at right angles to the line of sight. The transit was sighted upon cross-section paper pasted on one of the windows at the top of the building. The result in both attempts was the same—no movement detected. The third and last method was with the use of plumb bobs as pendulums. From a 2 x 6 plank, wedged diagonally between an interior column and the outer wall with the inner end at the ceiling and the other at the floor, were suspended plumb bobs of varying lengths. The plank picked up the vibrations and transmitted them to the pendulums. The plumb bobs with lengths of 45 inches to 47 inches were more subject to agitation than those longer or shorter. The stronger the wind the greater was the amplitude of the pendulums. Sometimes they swing over seven inches.

With these results and observations to work upon and at a suggestion from Professor P. W. Ott, of the department of mechanics, instruments are being developed at the present time to record the sway of buildings. This suggestion was to suspend a point in space within the building, and let the buildings sway or move about this point. This point in space could be the end of an indefinitely long pendulum. This procedure was impossible, but we are using an arrangement that acts exactly in the same manner. (The sketch illustrates this set-up.) If the line AC, the pendulum, is parallel to BD, they will meet at infinity. In that case, the angles A' and B' should each be 90°. But if the angle B' becomes smaller than 90° and angle A' remains 90°, AC and BD will intersect but at a great distance away; in both cases, the pendulum AC will be indefinitely long, the result desired. Also, with angle B' smaller than 90°, the pendulum is more stable and is being so used in the ensuing experiments. It is impossible to suspend the point A by an indefinitely long wire, so the weight, representing the point A, is suspended out in space by the pointed steel rod AB and the wire AD. D must be directly and vertically over B. The wire is fastened to the wall at D, and the hard point on the rod bears against a hard plate on the wall at B.

This pendulum was set up on the thirty-seventh floor of the A. I. U. tower, and during a thirty-mile wind gave a fairly constant motion of one-tenth of an inch. The next step was to record this movement on paper. It was decided to use a moving strip of paper in order to make a continuous record of one hour or longer. As the movement was so slight, it was feared that by attaching a pen to the weight that the friction would be too great and possibly make the readings inaccurate. As the wind pressure recording boxes use a photographing device, the same principle will be used, but on a more scientific basis. A source of light, about one-tenth the size of a pin head, will be placed under the weight and will shine through the camera on to the moving strip of sensitized paper. The Sway Photor, as this apparatus is

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called, will be fastened to the floor and will move with the building; the light standing stationary. The distance between light and the lens and the paper and the lens are so proportioned that the movement recorded on the paper will be two or three times the actual movement of the camera, that is, the movement of the building. As the camera sways and the paper moves, the minute beam of light will plot a wavy line (see sketch).

The Sway Photor will be electrically connected with all the other types of apparatus and will be so timed that the records of the wind direction, wind velocity, wind pressure, and sway apparatus at any period can be easily compared.

As the Sway Photor will record the sway in only one direction, the use of two at right angles to each other are required in order to give the two components of the motion.

Declaring that the engineering achievements of George Washington have been "lost in the dazzling light of the halo of his glory as a soldier," the American Association of Engineers recently said that extensive research of history has revealed that George Washington, who commenced his engineering career at the age of sixteen, was the real planner of the national capital—not Major Charles L'Enfant, who is popularly believed to have been the leading factor in this great engineering achievement.

Tile were first made in Ohio in 1830, near Lorain.